the substrate **206** before etching the conductive layers **202**, **204** and insulating layer **208** to define the comb fingers **214**, **216**.

A third embodiment of the present invention is illustrated in FIGS. **3A–3I**, which shows a method of fabricating a multi-layer vertical comb-drive structure of the type shown in FIGS. **1B–1C**. In this method, one set of comb fingers has two layers, while the other has only one layer. FIG. **3A** shows a structure **300** containing first conductive layer **302** and second conductive layer **304**, and first and second insulating layers **306** and **308**, respectively. Also shown is optional substrate layer **310**. Structure **300** may be identical to substrate **200** of FIG. **2A**. Conductive layers **302** and **304** are preferably silicon, while insulating layers **306** and **308** are preferably a silicon oxide formed from thermal oxidation of silicon wafer layers **302** and **3041** which are then bonded together.

In FIG. **3B**, a first masking layer **312** (e.g. silicon oxide, aluminum, photoresist) is deposited and patterned on top of first conductive layer **302**. Some of the remaining portions of the masking layer cover areas that will eventually become the first comb fingers. Next, in FIG. **3C**, a second masking layer **314** (e.g. photoresist) is deposited on top of first masking layer **312** and then removed according to a second pattern, defining the location of eventual comb fingers. Layers **312** and **314** contain different types of masking material, so that one can be selectively removed without affecting the other. In FIG. **3D**, regions **316** of first masking layer **312** that are not covered by second masking layer **314** are removed. This ensures that the second mask **314** defines the comb structures. Therefore, the alignment between the first mask **312** and the second mask **314** does not affect the comb widths. Next, in FIG. **3E**, first conductive layer **302**, first insulating layer **316**, and second conductive layer **304** are etched, e.g., using deep reactive-ion etching (DRIE) to create two sets of comb fingers **322**, **324** that will respectively become second and first comb fingers. The second masking layer **314** is then removed to create the structure of FIG. **3F**, which is etched using DRIE or other anisotropic silicon etching methods to remove the first conductive layer **302** from alternating comb fingers. The resulting structure is shown in FIG. **3G**. The fingers are then undercut in FIG. **3H**, followed by optional removal of portions of the first and second insulating layers **306** and **308** and remaining first masking layer **312** to reveal an actuator **330** of FIG. **3I**. Insulating oxide layers may be removed using a timed HF etch. In the embodiment shown, second comb fingers **322** are connected to a second comb bridge in a plane parallel to the plane of the paper, either above or below the page. The second comb bridge may be connected to the substrate through a torsion hinge or flexure that allows movement of the second comb structure. One method to operate actuator **330** is to apply a voltage V to the second comb fingers **322** and a bottom layer **324**B of the first comb fingers **324**, while a top layer **324**A of first comb fingers **324** is grounded, causing an electric force that moves the second comb fingers **322**.

Note that the method illustrated in FIGS. **3A–3I** can also be used to create an actuator in which the first comb fingers have a single layer and the second fingers have two layers, in which case application of a voltage causes the second fingers to rotate downward. This method requires slightly different patterning of the two types of masking layers.

Actuators of the present invention may be used for any suitable application. Two-dimensional actuators may be fabricated using similar processes. Depending on the application needed, additional steps may be added into the fabrication process to create an integrated device. Metals may be evaporated, sputtered, or electroplated onto the substrate using methods known in the art.

In both embodiments of the fabrication method shown, all of the fingers are formed in a single process in a single multi-layer wafer structure, thus providing for very high precision in alignment of the comb fingers.

It will be clear to one skilled in the art that the above embodiment may be altered in many ways without departing from the scope of the invention. Accordingly, the scope of the invention should be determined by the following claims and their legal equivalents.

What is claimed is:

1. A method of fabricating a multi-layer vertical comb-drive structure comprising:

a) providing a multi-layer structure, the multi-layer structure including:

i) a first conductive layer;

ii) a second conductive layer;

iii) a first insulating layer disposed between the first conductive layer and the second conductive layer; and

b) etching a pattern in the first conductive layer, the insulating layer, and the second conductive layer, wherein the pattern defines a plurality of comb fingers of a first comb structure that interdigitate with a plurality of comb fingers of a second comb structure.

2. The method of claim **1**, wherein the multi-layer structure includes a second insulating layer disposed between the second conductive layer and a substrate layer.

3. The method of claim **2**, wherein the substrate includes a material selected from the group consisting of silicon, silicon-germanium, silicon-carbide, nickel, and gold.

4. The method of claim **1** further comprising etching a portion of the second insulating layer and a portion of the substrate layer to release the comb structures.

5. The method of claim **1** further comprising disposing a masking layer on top of the first conductive layer prior to step b).

6. The method of claim **5** further comprising, prior to said step b), removing selected portions of the masking layer to expose selected portions of the first conductive layer.

7. The method of claim **6** wherein step b) includes etching the exposed portions of the first conductive layer, the first insulating layer and the second conductive layer.

8. The method of claim **7**, wherein the selected portions are exposed by disposing a second masking layer over selected portions of the masking layer, wherein the second masking layer is resistant to an etch process that removes portions of the masking layer that are not covered by the second masking layer.

9. The method of claim **8** wherein step b) includes etching the exposed portions of the first conductive layer, the first insulating layer and the second conductive layer.

10. The method of claim **9**, further comprising removing selected portions of the second masking layer to expose portions of the first conductive layer.

11. The method of claim **10** further comprising etching the exposed portions of the first conductive layer.

12. The method of claim **11**, wherein the multi-layer structure includes a second insulating layer disposed between the second conductive layer and a substrate layer.

13. The method of claim **12** wherein the second insulating layer includes a material selected from the group consisting of silicon-nitride, silicon-oxide, silicon-carbide, quartz, high resistivity silicon, high resistivity silicon germanium, polyamide, or a polymeric film.